

APPENDIX F

SWAB EUE DESIGN and DEVELOPMENTAL TESTING

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- Figure 2 - Added thumb screw and insert to battery access panel
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SECTION I
ASD DEVELOPMENTAL DESIGN

Figure 1
Nomex Cover

- To protect from possible flame sources and allow the user to attach the device to an ISS wall, the ASD Jacket was developed as shown below. It is a one piece design using flight approved Nomex with a see through Teflon window as well as a rear flap with a hole cutout that can be lowered to access the ASD Battery Access Panel.



Figure 2
Thumb Screw and Insert to Battery Access Panel

- To allow a more user-friendly access to the battery pack if required to change out the battery, a threaded insert is inserted into the ASD Battery Access Panel that is specified for nonmetal structures and allows the use of the thumbscrew shown below. The thumbscrew will allow the user to access the battery without any special tools reducing crew time and complexity.

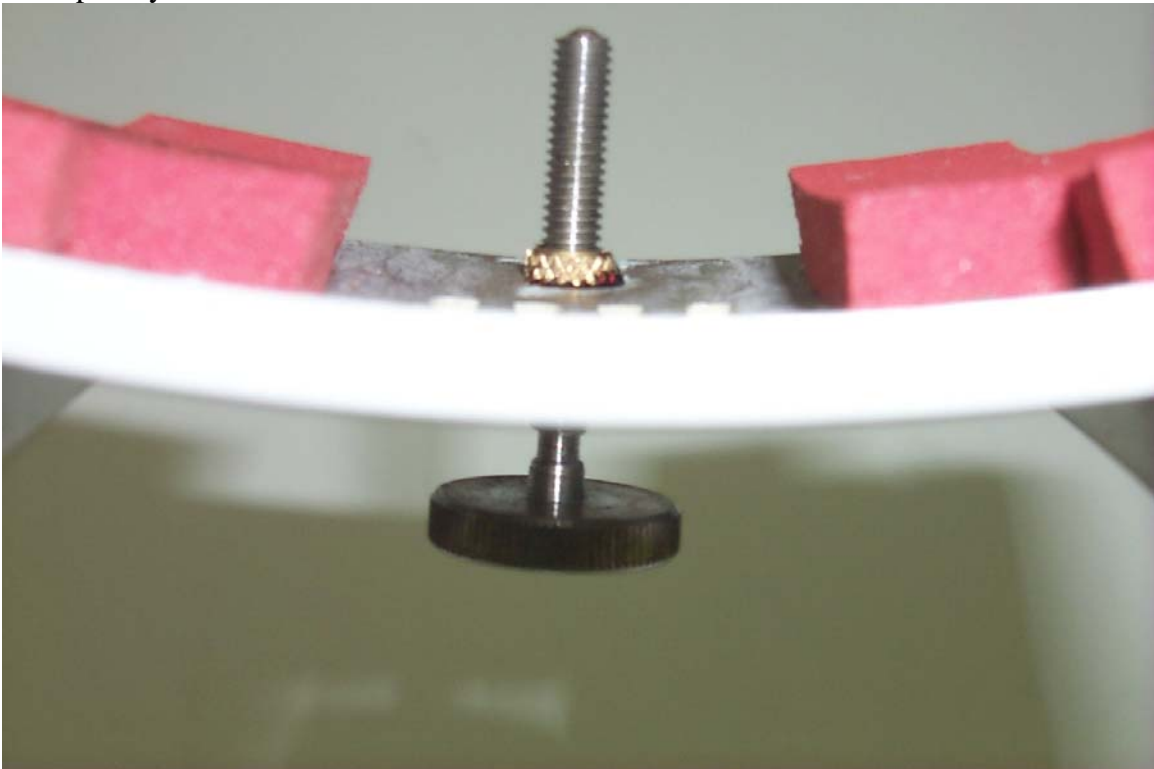


Figure 3
Control Panel Decal

- To assist in operation of the ASD, a decal was configured that more accurately describes the operational buttons. Human factor engineering personnel approved the nomenclature and style.



Figure 4
PVC coated conductors replaced with Mil-spec wire

- One of the primary objectives for getting the COTS ASD to a flight ready status is to replace all COTS PVC coated wiring with flight approved and proper derated wiring. The wire chosen utilizes the standard MIL-SPEC Teflon coated and is more than 50% derated for this application. The figure below shows the new MIL-SPEC wire utilized for the ASD.

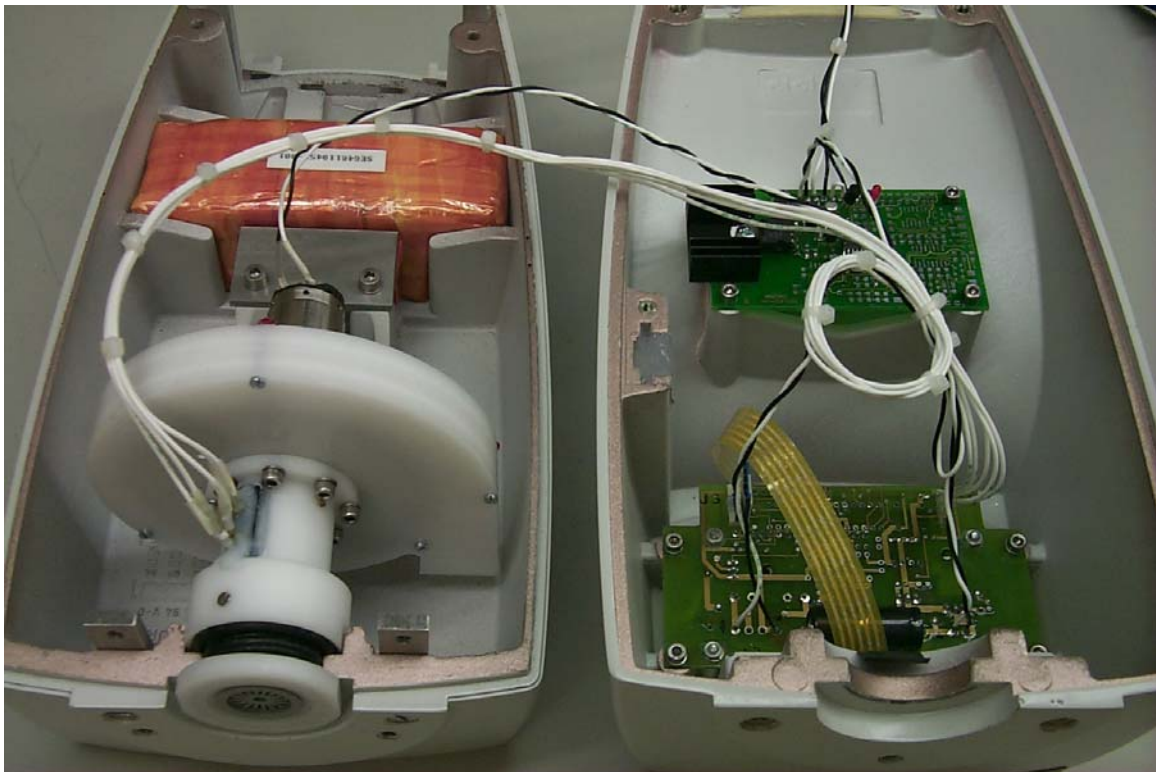


Figure 5
Removed External Charge Jack Connection

- Because the final ASD design will be powered by a non-rechargeable battery and to satisfy one of the safety hazard controls for the ASD/ASD Battery Pack, the charging plug and wiring was removed from the ASD. In addition, the hole was filled with RTV and tape placed over the hole to prevent any possible debris access although the ASD Jacket will also cover up this access hole. The wires are also removed from the ASD charging board so there is no possible short circuit possibility to occur.

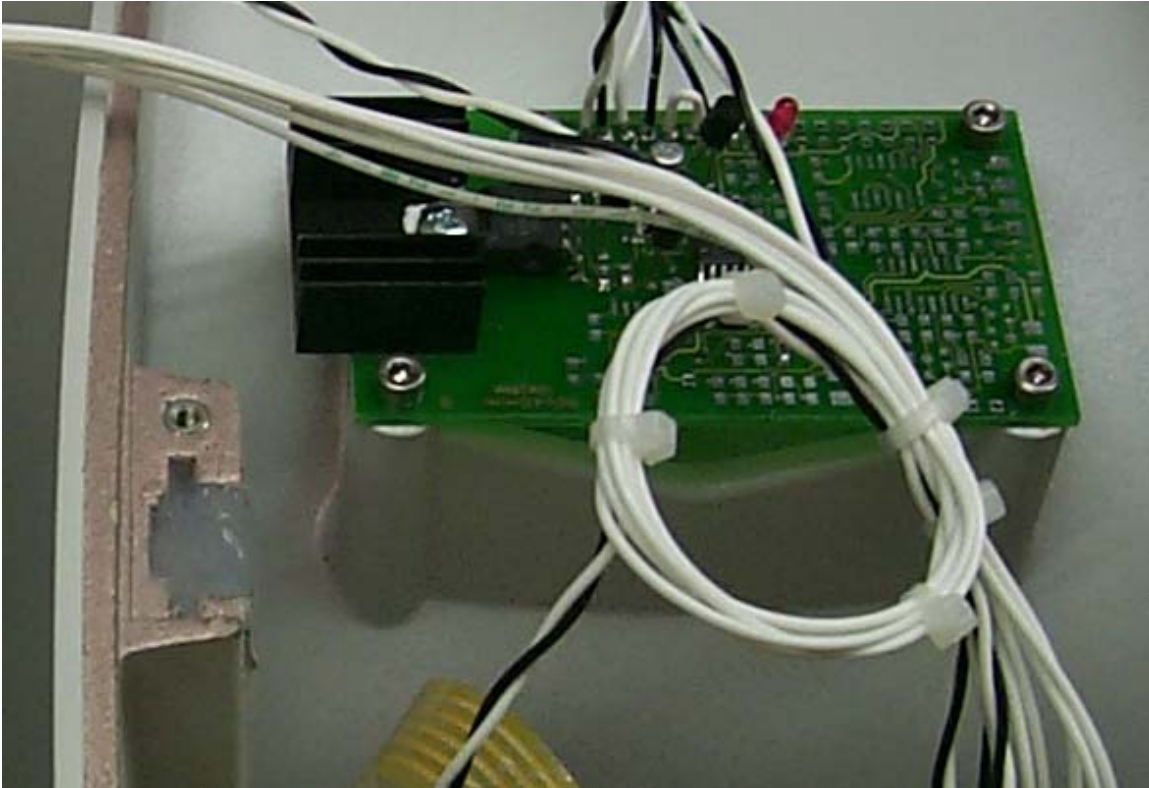
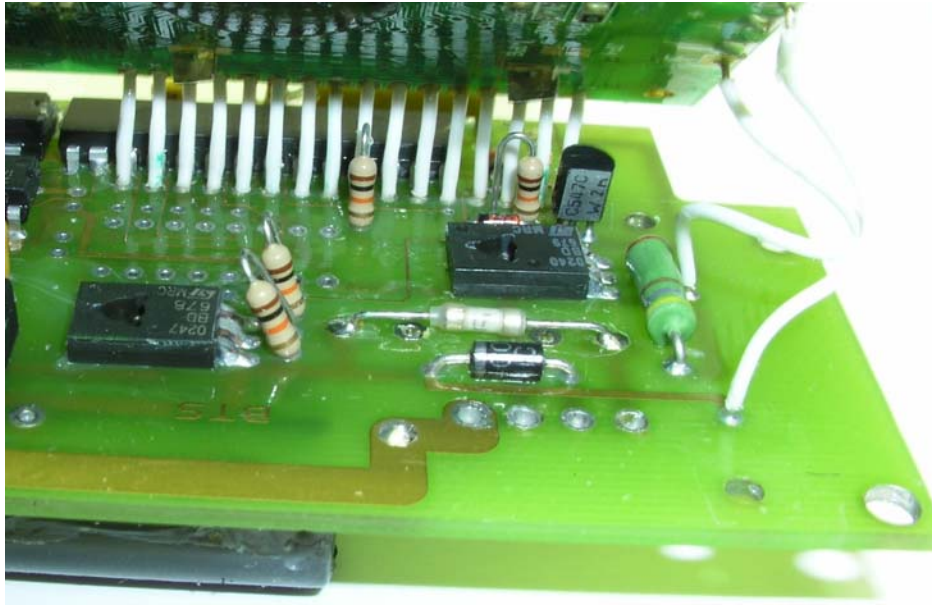


Figure 6
Glass Fuse Replaced w/ PICO (solid state) Device

- To eliminate as much glass sources as possible and to eliminate weak points in the design, a glass fuse with standoff was replaced by a proper derated pico fuse that was chosen to also protect the ASD/ASD Lithium Battery from a short circuit scenario.

PICO FUSE



GLASS FUSE

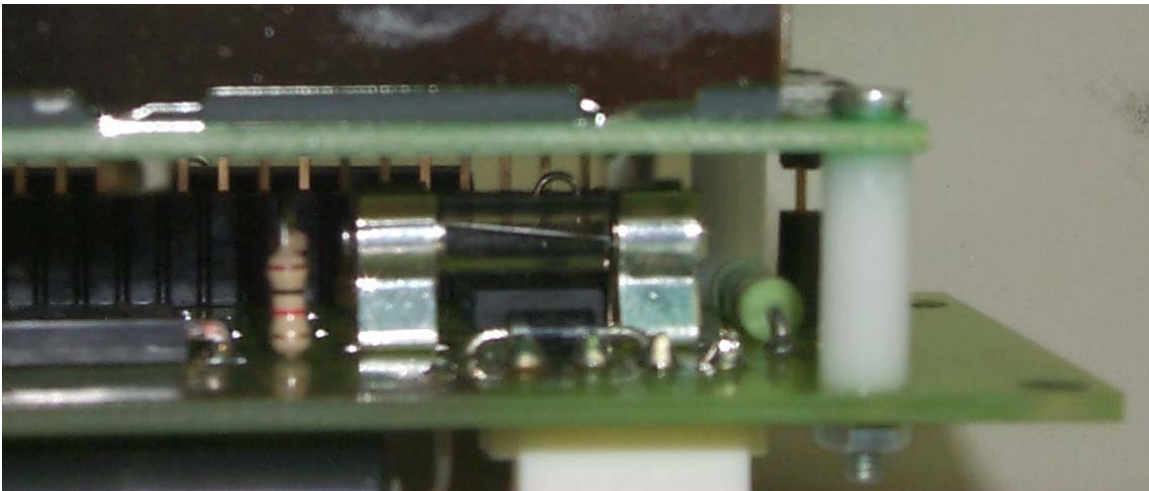
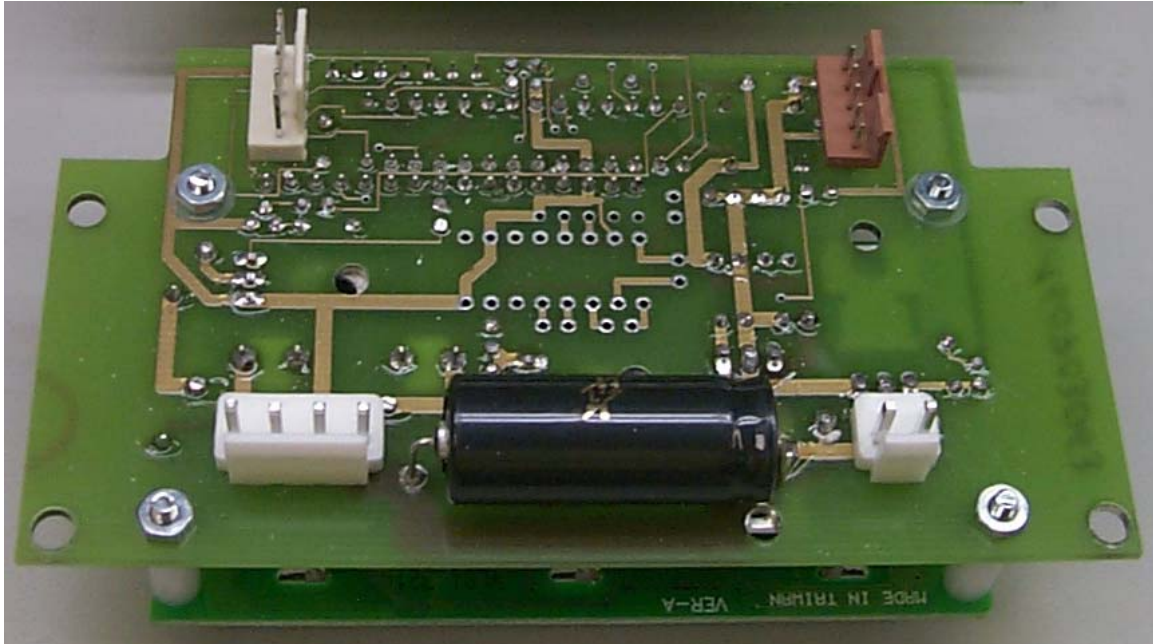


Figure 7
Removed PCB Connectors and Direct Mounted Components to PCBs

- To eliminate potential vibration weak components and connectors for the ASD wiring, the wiring connectors were removed from the systems PCB and power PCB and wires were soldered directly to the PCBs. In addition, many of the larger components such as this large capacitor in the picture were staked using RTV. Finally, all the PCBs were conformal coated for short circuit protection with improved heat dissipation with moisture protection.

BEFORE



AFTER

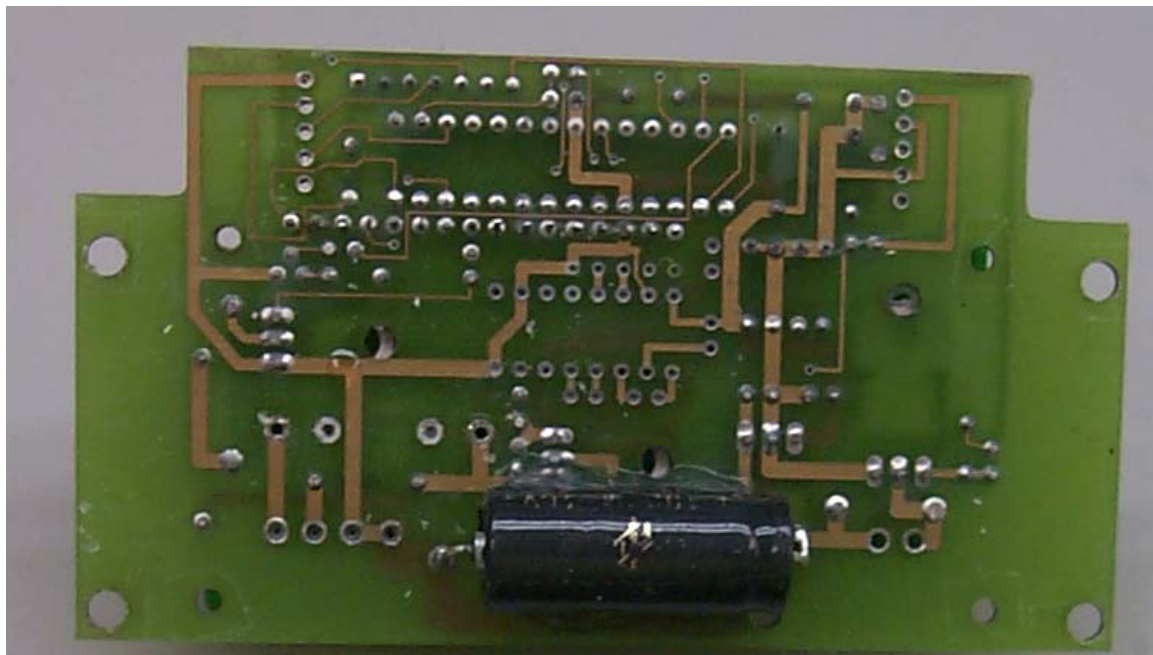


Figure 8
LCD Board Sockets Removed and Wiring is Connected Directly to Control PCB

- The LCD PCB, which is the top most PCB shown below was originally, attached directly to the Control PCB via standoff style connectors with pins. After a thorough inspection and some initial testing, these connections were determined to be high potential sources of failure from vibration and shock so the connectors/standoffs were replaced with traditional standoffs to separate the boards and the necessary connections were made by direct soldering of wire jumpers.

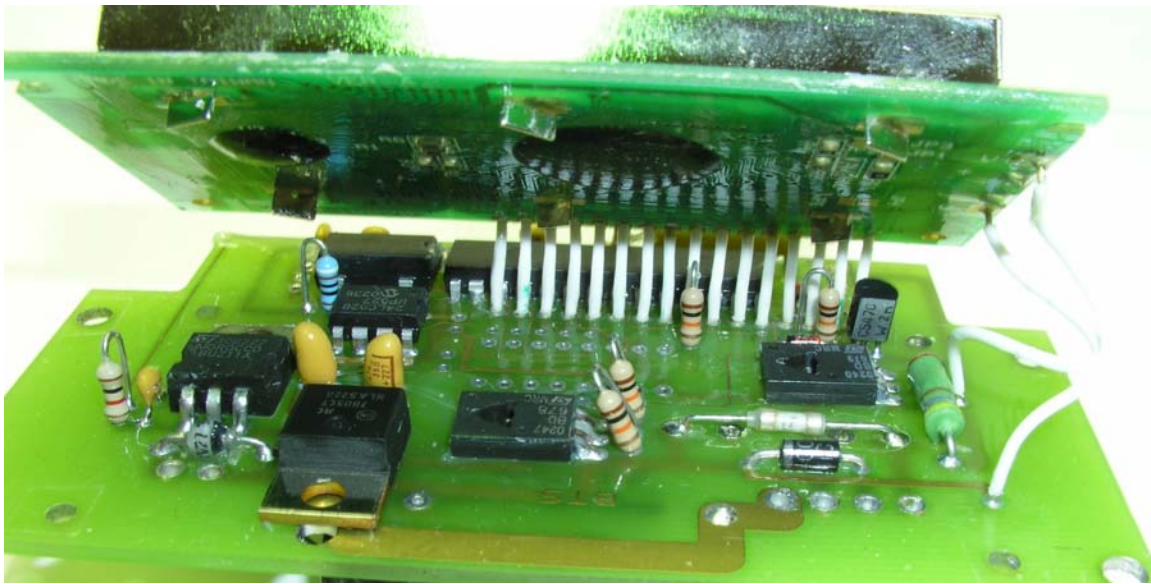


Figure 9
Integrated Circuits Sockets Removed and Connected Directly to PCB

- A final developmental design change made for the ASD was to also direct solder the Integrated Circuits to the Control PCB. Originally, the ICs were connected to a socket bridge and again concerns were raised about the structural design of these sockets so the change was made.

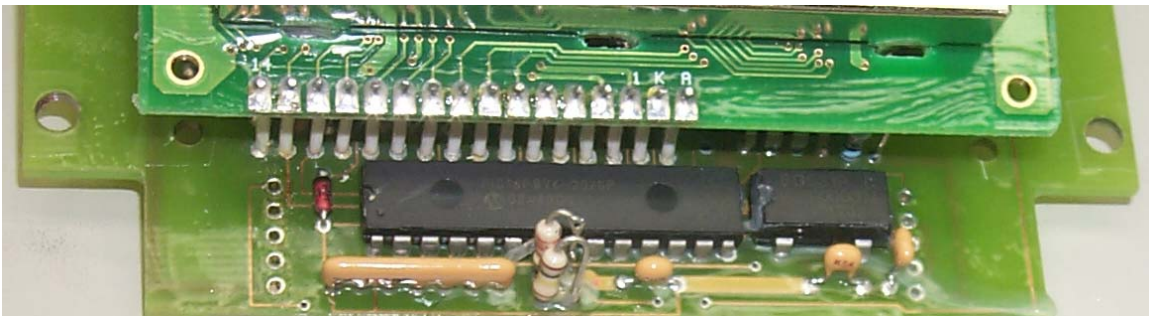


Figure 10
Redesign of the ASD Battery Capacity Feedback Circuit

- Changing the principle power source of the ASD from a rechargeable NiMH battery to a Primary (non-chargeable) Li-BCX battery changed the available operating voltage range. The COTS battery (NiMH) voltage range is approximately 18.2vdc for a fully charged OCV (Open Circuit Voltage) to a 14.4 vdc CCV (Closed Circuit Voltage). The Flight battery (L-BCX) range is approximately 19.5 vdc OCV to 10.0 vdc CCV. The ASD in its COTS configuration will operate from 21.0 vdc to 14.4 vdc. This lower cut-off level is set so as not to over discharge the NiMH battery. Over dis-charging of a Re-chargeable battery can shorten the useful life and could reverse the polarity of a cell ultimately drain the capacity of the entire battery pack and rendering it defective. The intention of using a non-rechargeable battery is to gain useful life and in that end an exploration was undertaken to determine the lowest operational voltage of the device. By the measurement, method the lowest operating voltage for the ASD is 12.37 vdc. The MCU (micro-controller circuit) battery feedback circuit sensed an equivalent voltage of 3.63 vdc. It was reasoned that replacing one of the two voltage ladder resistors was least invasive and since the value increased no increased power dissipation needed to be compensated for in the ladder. The equation below demonstrates the derivation of the final R9 value.

ASD Cutoff Voltage

Supply (NiMH) Battery voltage at Cutoff:

$V_{in} = 14.4v$ Indicated Percent Battery Capacity Remaining = 2 %

$V_{out} = 3.58v$ Measured Voltage

$R8 = 100k$ ohms

$R9 = (_x_) ?$

Equation to predict value of R9:

$$\frac{V_i}{R9 + R8} \times R9 = V_o$$

Solving for R9 gives:

$$R9 = \frac{R8}{(V_i/V_o) - 1}$$

If V_o measures (3.64 vdc) at 2 % Capacity remaining;

then,

$R9 = 42,032$ ohms

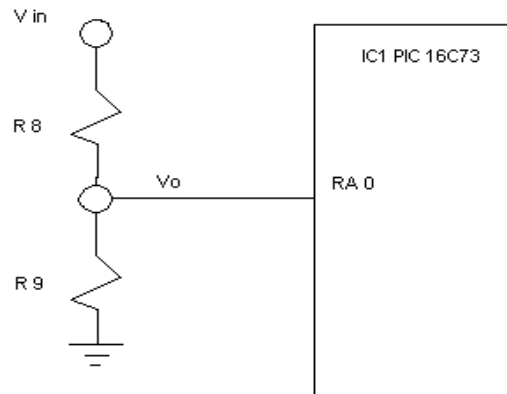


Figure 11
Voltage Ladder Modification Testing

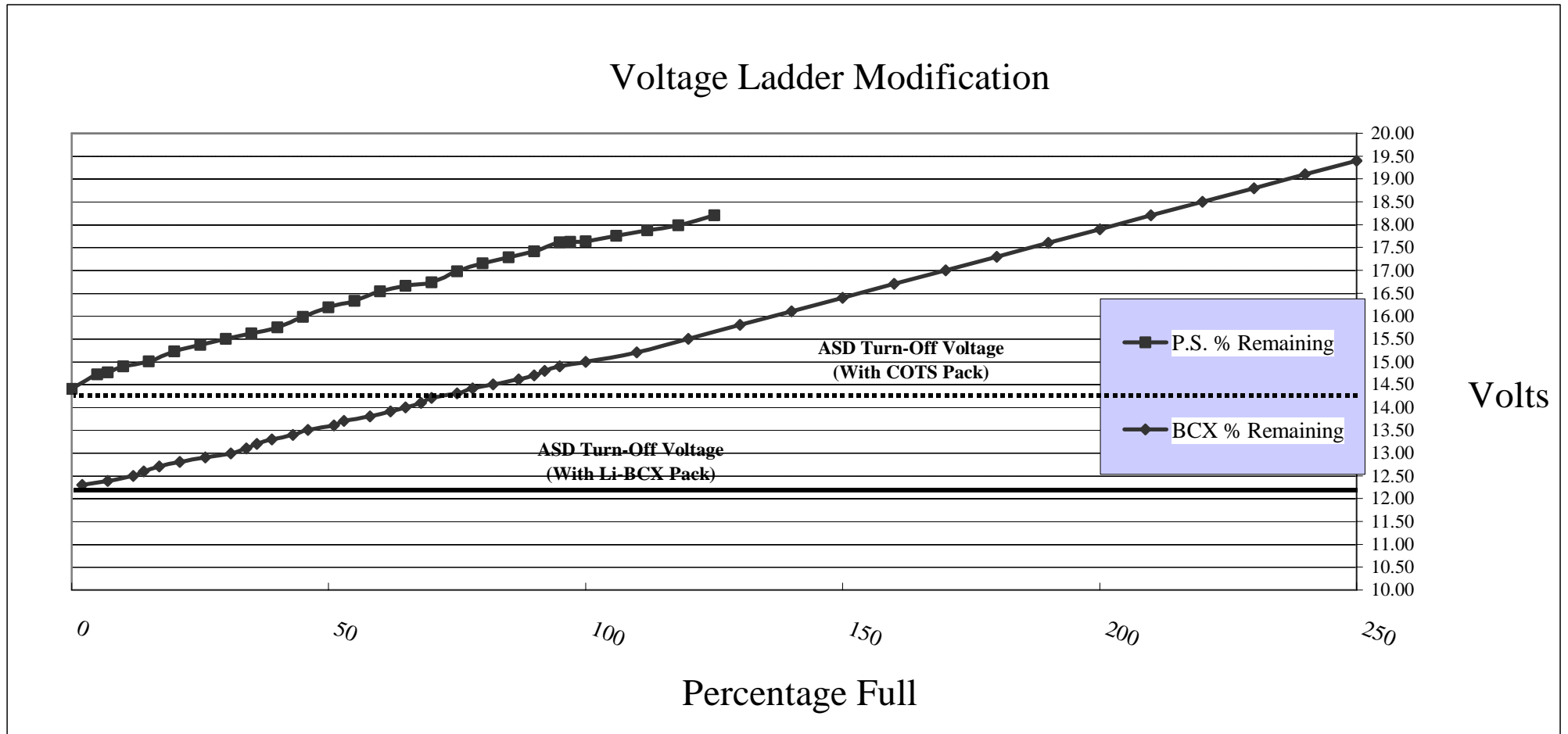


Figure 12
Increased ASD Air Outlet Vents Dimension

- After the new ASD Battery Pack was assembled and inserted into the ASD, the battery access panel vent shown below were slightly blocked by a Nomex pull tab on the battery pack so the air vents were extended further to allow more air flow out of the ASD.

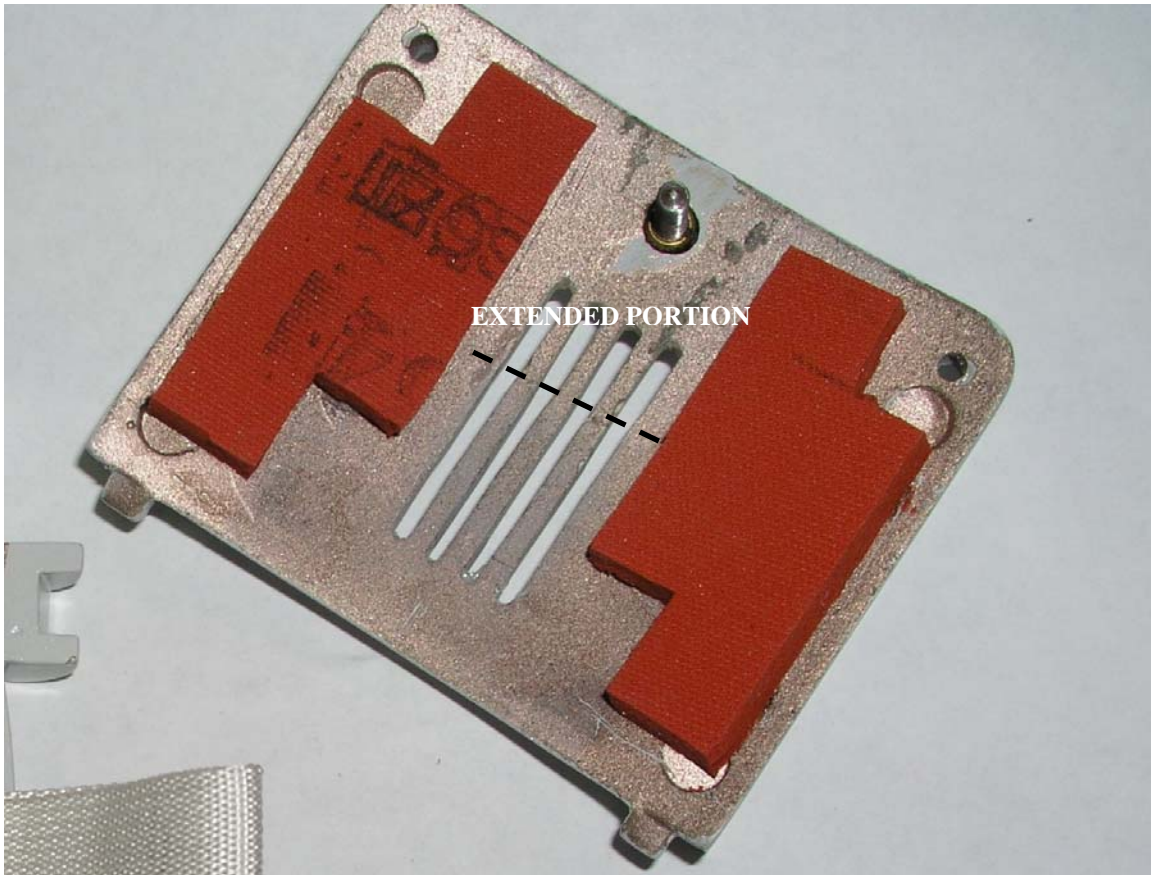
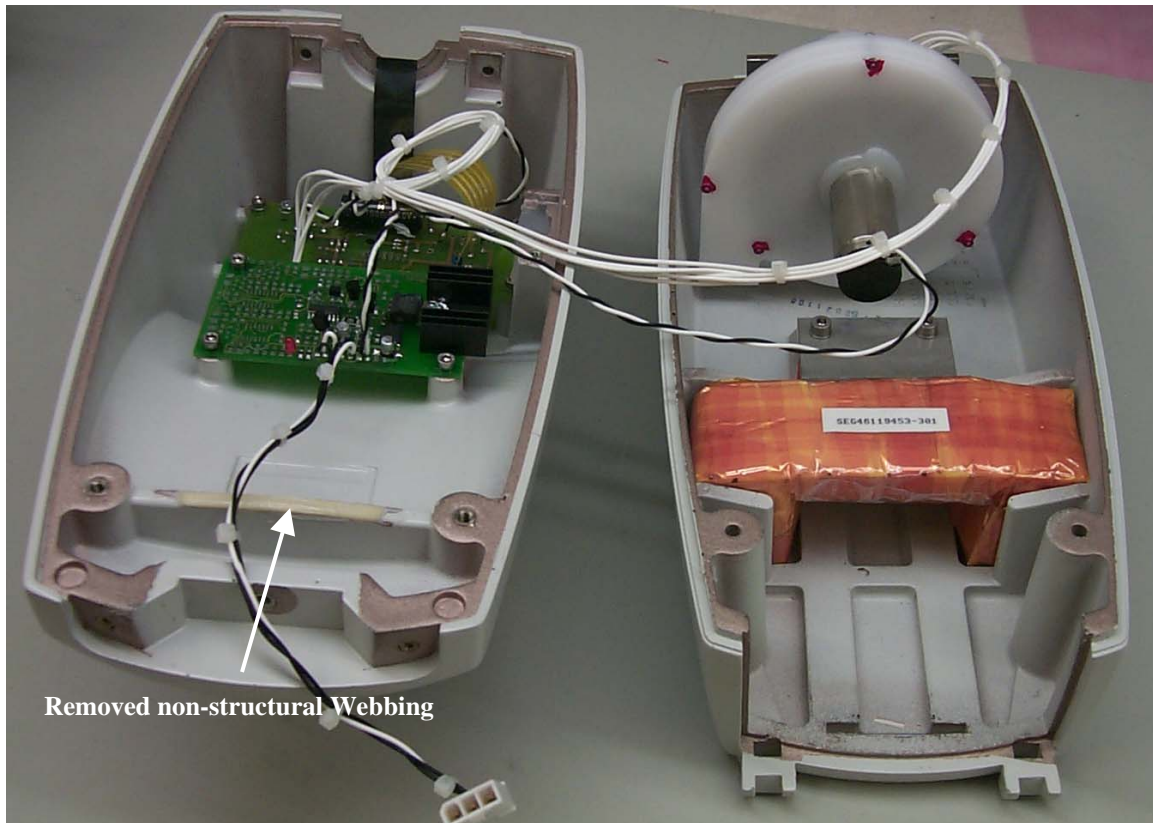


Figure 13
Battery Guide and Non-Structural Component Removal

- To assist with protecting the battery from improper insertion into the ASD cavity and protect the battery pack from shock and 1-g maneuvering operation (upside down) a wedge shaped L200 Foam cutout covered with Teflon tape was inserted inside the ASD compartment as shown below. In addition, to prevent the power cable and battery connector from snagging as it is being inserted into the ASD, a non-structural web was removed from the housing. The web was originally used to help maintain the COTS battery pack position but because the battery guide was implemented, this feature was no longer needed.



SECTION II
ASD DEVELOPMENT TESTING

Figure 14
ASD Power Profile – Current vs. Battery Capacity

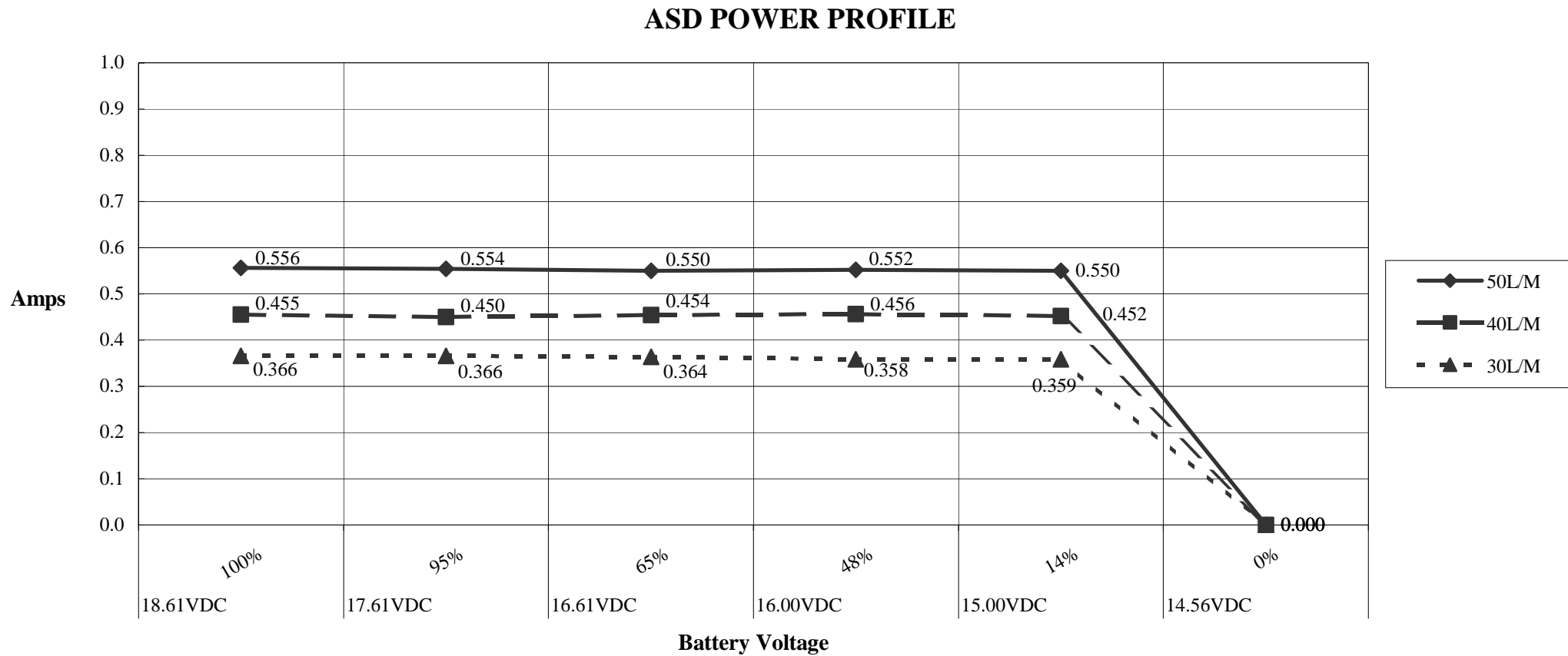


Figure 15
ASD In-Rush Current Profile

ASD In-Rush Current

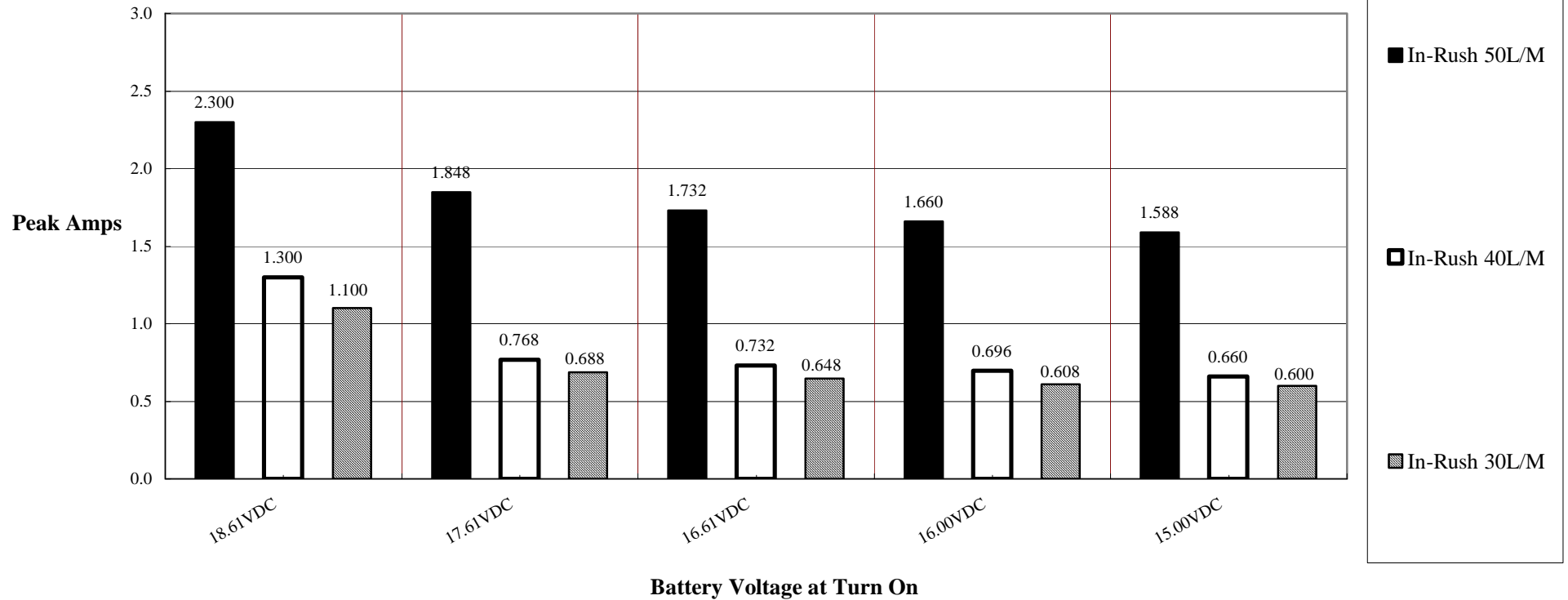


Figure 15 Continued
ASD In-Rush Current Profile (at 50 L/min) – Measured

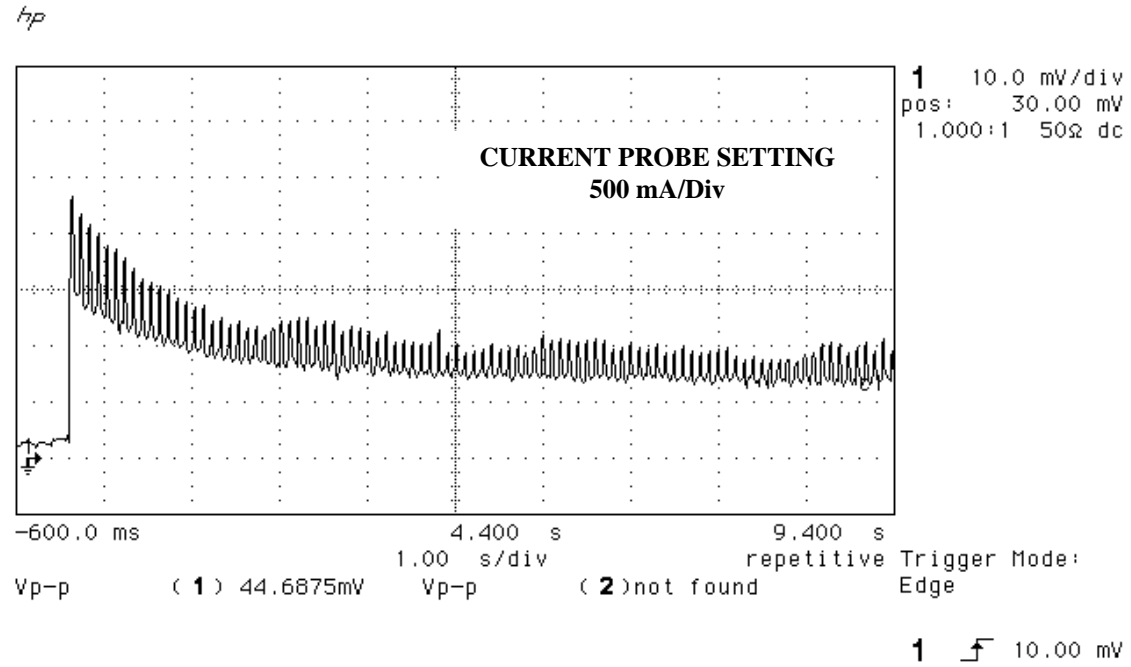
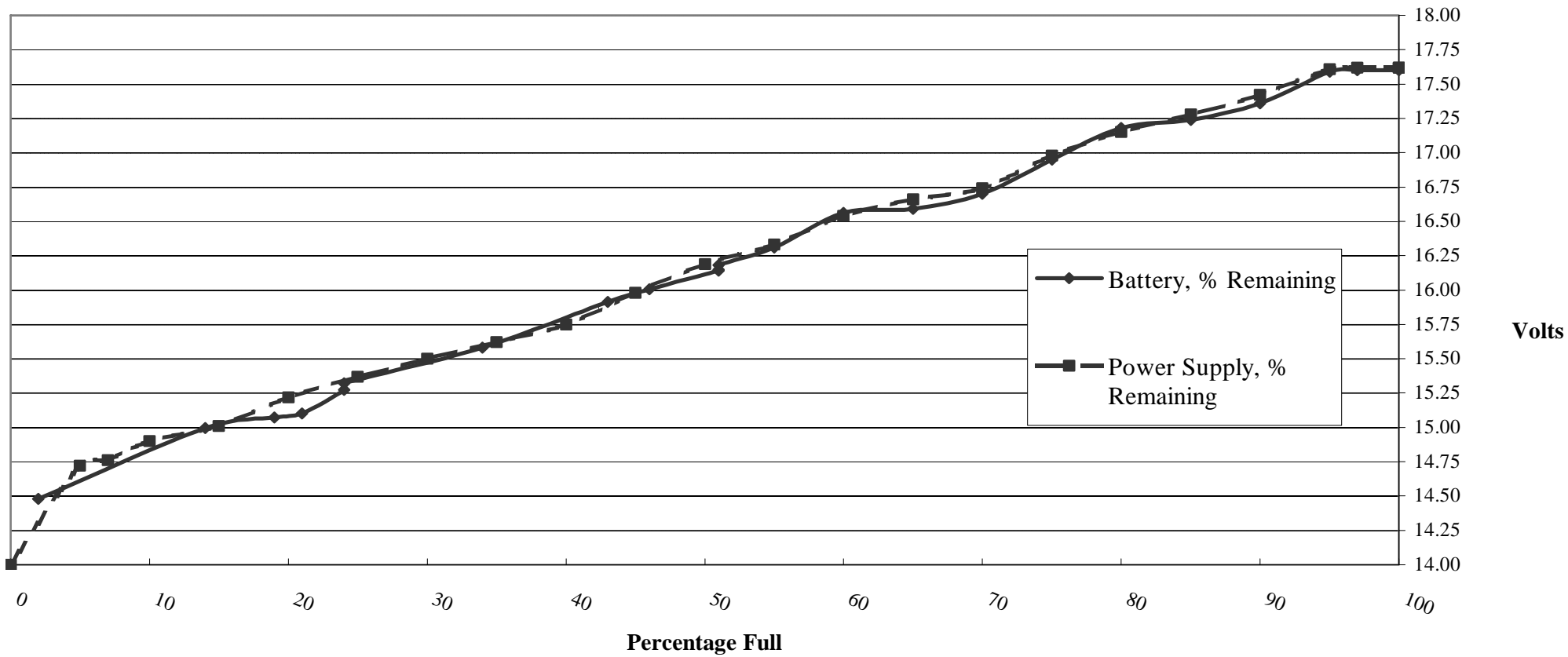


Figure 16
Discharge Profile – Power Supply vs. Battery Pack

ASD Discharge Profile - Comparison Between Power Supply and Battery Power

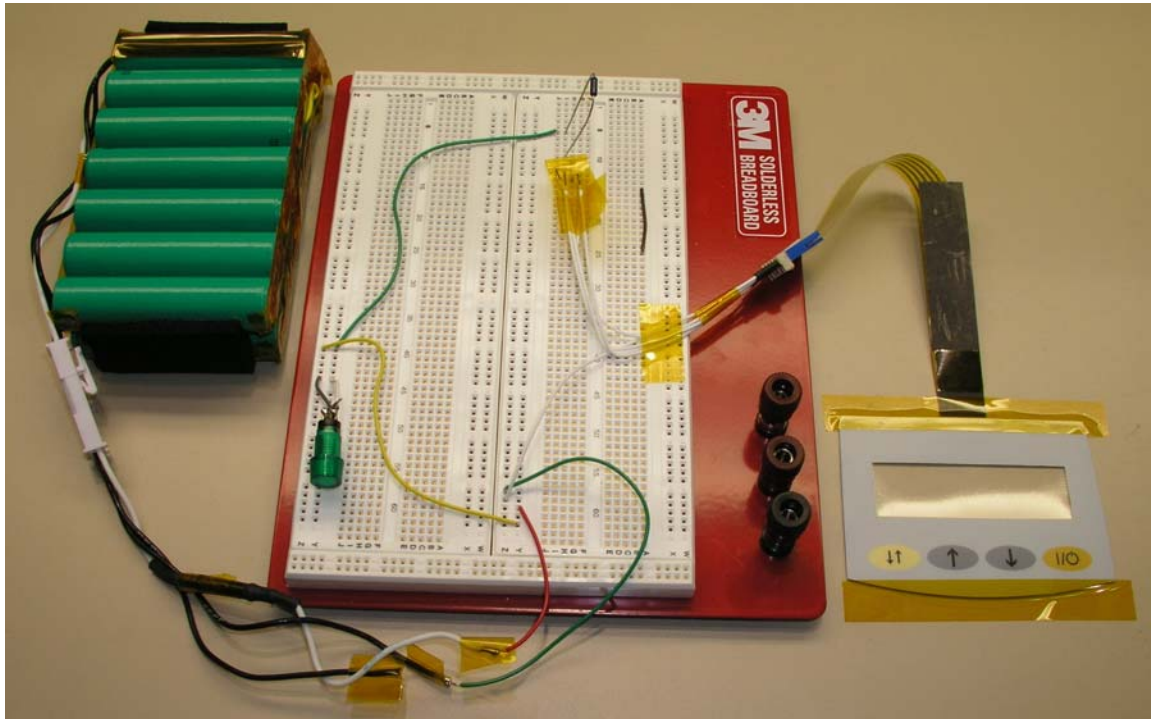


ASD Power Disruption Testing

In the event that power was somehow disrupted or removed from the ASD and the unit turns off, the device must remain off if the power is reapplied back to the ASD and not immediately turn on by itself without pressing a button. To satisfy this safety requirement, a number of tests were run. The ASD was first connected to a DC power supply and turned on to run. While running the power supply was turned off and immediately turned back on. After completing this test, the ASD turned off immediately after removing the power from the power supply and remained off even after the power was reapplied. The test was then repeated with a battery pack simulating true flight configuration and the battery pack was unplugged from the ASD while running then plugged back in to restore power. The ASD turned off after the battery was unplugged and remained off after it was reapplied. The ASD has a built in automatic turn-on prevention system designed in the unit and the user must press the “ON” button to activate the ASD after power has been removed from the unit.

Tactile Membrane Foil Testing

Because of unfamiliarity with use of the Tactile Membrane Foil button operation and their lifetime limits, the experiment team tested various conditions of the ASDs tactile membrane foil with repeated button presses at different voltage levels. The test setup shown below was utilized and approximately 10,000 button presses were achieved before vendor data was found to indicate that the tactile membrane foil is rated for up to 1 million cycles and rated for up to 1 A of continuous current. The current levels through the membrane foil only reach about 900 μ A, which is more than adequately derated.



SECTION III
ASD LITHIUM BATTERY DESIGN DEVELOPMENT

Originally, the COTS ASD came equipped with a COTS developed battery pack configured with 14 NiMH cells that were rechargeable. The ground application of this type of chemistry was ideal however after some testing and research into the NiMH pack it was determined that the discharge rate of this NiMH pack was too great to support long duration missions (>4 months) despite how many were flown as back-ups and the original design of the hardware did not include a method to recharge the packs on orbit. Therefore, a new battery was researched and configured to power the ASD. Given the requirements of the experiment:

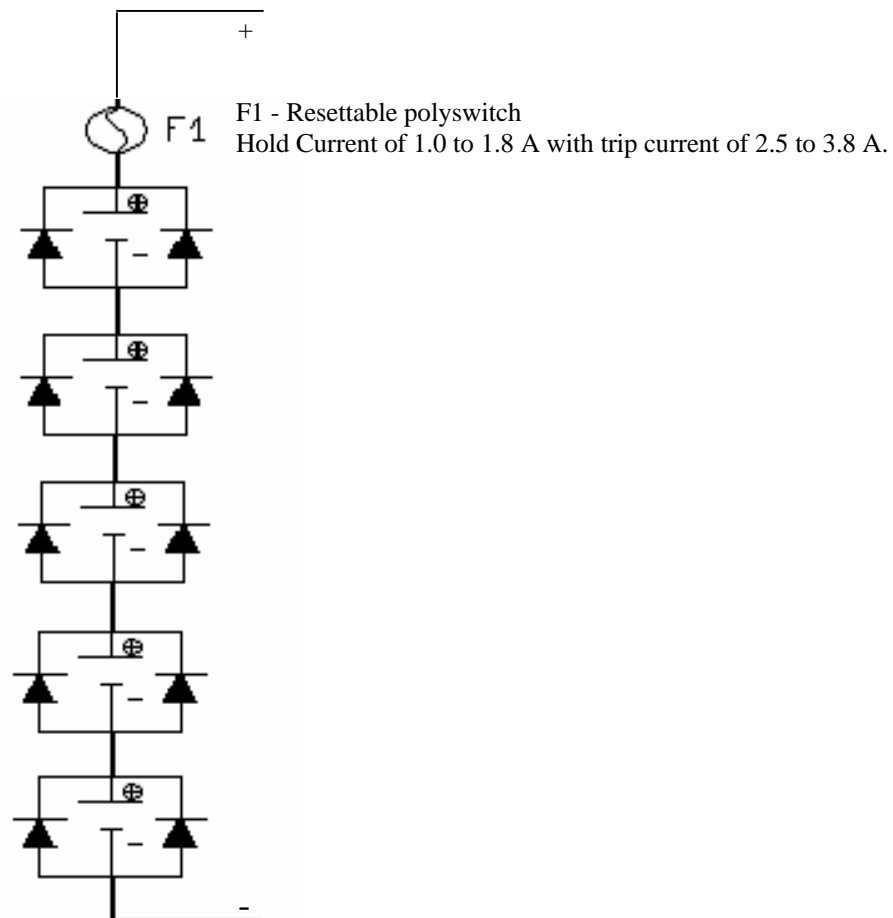
- Portable Air Sampling Device (ASD)
- Battery chemistry selection that would power ASD and be able to hold charge after ~2 thru 3 months of non-use
- Eight (8) hours of total hardware usage time per Increment

and the requirement of the ASD operation:

- Operating Voltage: 12-19 Vdc
- Peak Inrush Current: 2.3 A
- Steady State Current: ~0.5 A
- Battery pack assembly must fit inside ASD's battery compartment

A Lithium Bromine Complex chemistry cell type was chosen after researching and receiving recommendations by NASA EP5 battery experts. The battery cells are Flight approved and certified primary (non-rechargeable) Li-BCX C size battery P/N 3B4250-ST provided by USA. These cells have undergone extensive testing and have extended shelf life and storage capacities that were ideal for the experiment's use. However, the ASD required at least 12 VDC power to operate the device so a pack was required configured. The ASD Lithium Battery configuration is described below.

- ASD Li-BCX Battery Pack Assembly
 - Five (5) Li-BCX C size cells P/N 3B4250-ST in series configuration
 - Dimension: 5"x2"x1"
 - Weight: ~3.5 lbs
 - Voltage (under load): 16 VDC
 - Total of ~8.5 hrs of use per pack
- Cell Safety Features
 - Internal 4 A pico fuse
 - Cell has been verified to be tolerant to smart internal shorts with low molarity (0.6M) electrolyte design
 - Cell packaging design prevents internal movements thereby preventing internal shorts.
 - Hermetic sealed enclosure
- Pack Safety Features
 - Two (2) resettable polyswitch thermal fuses with activation temperatures of 110 degrees C wired in series to monitor battery pack temperature
 - Two (2) parallel diodes per cell to prevent over-discharge
 - Keyed connector and shrink tubing covering exposed cell tabs, components, and overall assembly were used to prevent shorting



ASD Lithium Battery Schematic

Chemistry

Lithium Bromide Complex (Li-BCX)

Power

17VDC (OCV)

SECTION IV

ASD LITHIUM BATTERY DEVELOPMENT TESTING

A majority of the developmental testing for these battery cells was actually accomplished by the NASA battery group in EP5 and reviewed by the lead Bobby Bragg who approves all battery usage for flight. The Lithium Bromide Complex cells underwent extensive testing before approval of use including:

- Vacuum Leak Testing
- Vibration Testing
- Thermal Testing
- Short Circuit Testing
- Open Circuit Voltage Testing
- Closed Circuit Testing

All of these were completed at the cell level in large lots of battery cells. Because the experiment team required a battery that would not loose energy at the rate that the COTS Nickel Metal Hydride (NiMH) pack was loosing, the experiment team worked with the battery group to assist in the design of a pack configured using the Li-BCX cells. Given the power requirements of the Air Sampling Device, 5 cells in a series configuration was required but for the many safety controls other components of the battery pack were needed including 2 parallel diodes per cell as well as a polyswitch fuse for short circuit protection. The battery pack design was approved by EP5 and battery certification was approved. The final battery pack will require additional certification testing including additional workmanship testing such as vibration, thermal and vacuum testing at the pack level to verify proper construction. However, The SWAB Experiment team conducted other tests for performance verification using a class II pack that the experiment team assembled during ASD prototype development.

The experiment team conducted power profile tests on the ASD using the Li-BCX pack to verify that the pack was operationally identical to the NiMH rechargeable pack. In rush current tests were conducted as well as extended shelf life testing. During the extended shelf life test the experiment team discovered a feature of the ASD that was actually inhibiting the full potential of the Li-BCX pack. The Li-BCX pack nominal voltage level is less than the COTS NiMH pack but sustains the capacity at a lengthier time interval. However, the ASD has an internal circuit that compares the battery voltage to a “pre set” voltage range for the NiMH pack stored in the microprocessor and when the battery voltage approaches the set “lower” limit then the ASD will shutdown because not enough power is left in the NiMH battery pack to sustain operation and for prevention of overdischarge of the NiMH pack. The experiment team redesigned the voltage comparator circuit slightly by replacing two resistors to allow a more realistic voltage level for the Li-BCX pack. Now the ASD is optimized to be operated with the Li-BCX pack but still can be used with the other pack if required.

SECTION V
SWAB TUBE DESIGN DEVELOPMENT
AND TESTING

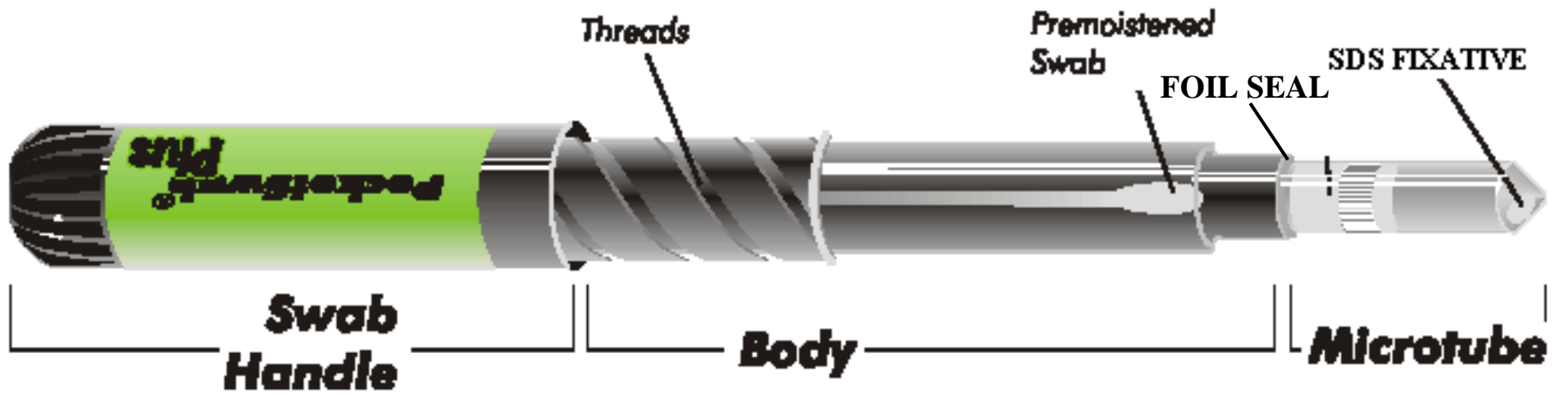
Originally when the experiment was introduced, the SWAB surface sampling protocols were to be accomplished using a part of the CHeCS surface sampling kit hardware. The CHeCS SSK contained a swab tube with sample vial that would contain 1 ml solution of buffer. However, after more development was completed for the experiment, the buffer solution was converted into a fixative solution in order to preserve the acquired sample for possible extended missions but the fixative was determined to be a tox level 1 which required levels of containment that the CHeCS plain swab tube in a vial would not provide.

The experiment team conducted market research for possible tubes with separate septums to contain the fixative or possibly other delivery methods for the fixative. A first attempt was to use a swab tube from Copan Industries that actually utilized a sponge soaked with the fixative in the bottom of the swab tube that would expel the solution after the sample was taken and the swab was inserted into the tube squishing the sponge. This design was actually presented at the Phase 0/1 Safety Review but was met with much resistance and the PSRP did not feel the sponge provided the necessary levels of containment. In addition, there were some concerns from the experiment team regarding how to get the swab pre moistened without additional hardware and the possibility that the swab tip would not be submersed in the solution released by the sponge. The experiment team conducted a few tests using the swab tube with sponge including a saturation point with the sponge. That is the experiment team determined the saturation point of the sponge. One of the concerns of the safety panel was that the sponge when compressed would expel the liquid out of the tube especially if the sponge was “soaked” of the solution. The experiment team conducted the saturation test and concluded that the sponge would hold about 1.5 times the amount of solution required for the experiment but was not nearly enough to have a factor of safety. After that and some additional market research, the Copan swab tube with sponge was abandoned.

Finally, a swab tube design was found by the experiment team which is developed by Charm Sciences Inc that seemed to be a perfect match for the experiments needs and engineering/safety requirements. The swab tube by Charm is actually a multiple piece swab tube with a micro tube that is sealed by a foil from the main tube body at the bottom of the tube. The main body of the swab tube is threaded so that the handle, which has a foam swab attached to it, would be threaded down the tube body and penetrates through the foil seal to the fixative solution after the sample was acquired. A picture of this tube is shown on the next page. This swab tube was brought back to the PSRP at a safety TIM for approval and proper hazard definition and was well received with one test required for leak validation.

The design of the swab tube from Charm is perfect for the experiment team’s use on the experiment but some minor additions were required. The label on the swab tube was going to be replaced by the experiment teams custom designed label from NASA’s Decal Design Production Facility in addition, the microtube was going to be more permanently secured/fastened to the tube body using epoxy and shrink tubing.

CHARM SWAB TUBE



SECTION VI
SWAB WATER BAG(S) DESIGN DEVELOPMENT
AND TESTING

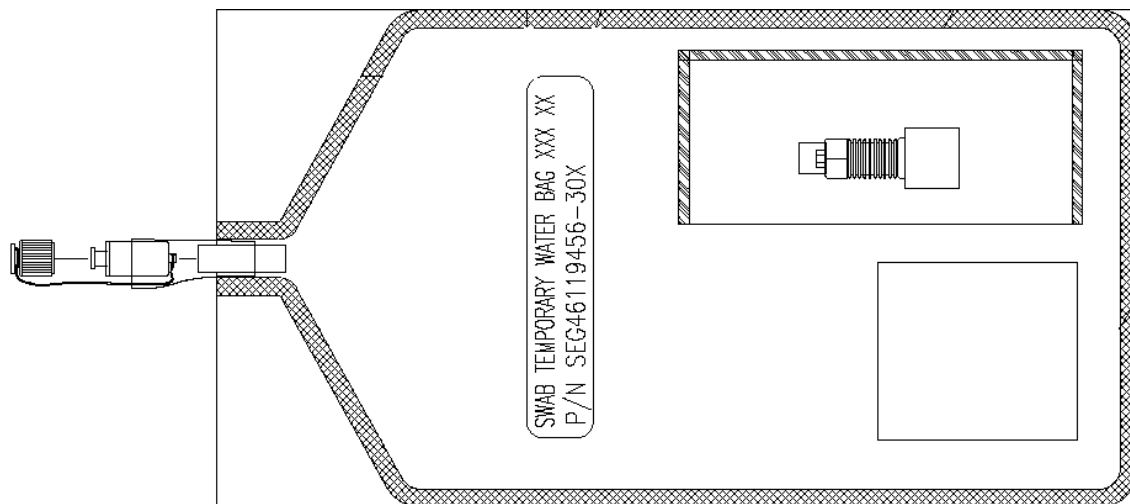
The Operational water sampling that already is being conducted on the ISS currently utilizes the American Fluoroseal water bag with Female luer lock attachment. Because American Fluoroseal already has a proven track record and the bags have been used extensively the experiment team also wanted to use the same type of bags from American Fluoroseal. But other than the bag, the bags are quite different from the CHeCS environmental sample bags.

The SWAB water collection system will utilize a dual bag water collection system. The purpose for the dual bag system is to be able to acquire the water sample from the water ports in the Russian module and then transfer the water into another water collection bag with the fixative solution. The fixative before water is introduced carries a tox level 2 level and therefore requires three (3) levels of containment and a high probability that the Russians will not allow the fixative bag connection to the water ports.

Therefore, the experiment team developed first the water bag to collect the water from the water ports. The SWAB Temporary Water Bag(s) were then developed consisting of the following key components:

1. American Fluoroseal Water Bag (P/N 2P-0270) with female luer lock connection (FTLL450)
2. Check valve with Female Inlet and Male Luer Lock Outlet (P/N 80363)
3. Cap with Tether (P/N 65451)

To support more efficient operations, the adapter probes that will be attached to the station ports and a BZK wipe to clean the ports will be attached directly to this Temporary Water Bag as shown in the figure below.

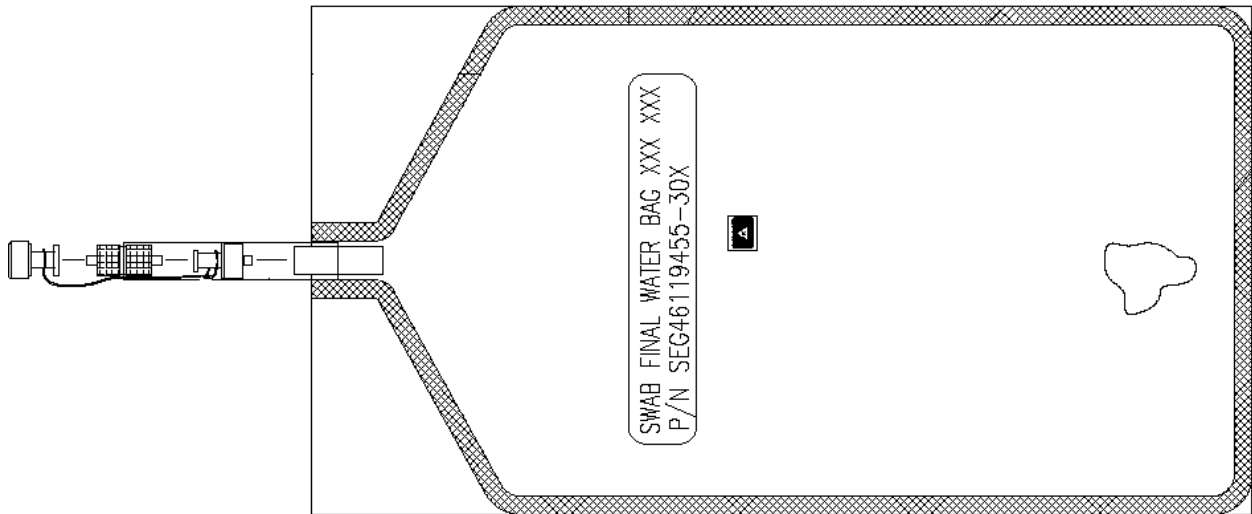


SWAB Temporary Water Bag Configuration

After the water has been collected in the temporary water bag, it will be brought back to the US lab where it will be connected to the SWAB Final Water Bag which will ultimately contain the water sample and return to earth. The final water bag is also the bag that contains the fixative. The actual water bag itself is the same water bag as the temporary water bag but is configured with different fixtures/components that enable it to be connected only to the SWAB Temporary Water Bags and in addition will not allow direct connection to the ISS water ports or adapter probes. Also, the check valve used for this water bag is a pressure activated one-way valve that will only allow water in, not out. Completing the assembly will be the fixative solution that will

be either contained as a water-soluble film bag or as freeze-dried pellets that dissolve once water is introduced in to the system. Therefore the final system is configured with the following and is shown below:

1. American Flouroseal Water Bag (P/N 2P-0271) with female luer lock connection (FTLL450) and Fixative
2. One way check valve with female luer lock inlet and male luer lock outlet connection (P/N 80066)
3. Male to Male Luer Fitting (P/N 20024)
4. Female Cap to fit Male Luer (P/N 65730) with Tether (P/N 65606)



SWAB Final Water Bag Configuration

To complete the final water bag system and to maintain the adequate levels of control, the final water bag is then placed inside a waterproof Bitran Ziploc style bag. Only during the water transfer from the temporary bag to the final water bag is the Bitran bag to be opened.